CLAIMS

What is claimed is:

1. An apparatus for communicating and laterally directing electromagnetic radiation, comprising:

a waveguide having a tip for communicating electromagnetic radiation in a propagation direction to the tip of the waveguide;

a transmitting surface on the tip of the waveguide;

a reflecting surface on the tip of the waveguide for internally reflecting electromagnetic radiation communicated by the waveguide in a direction lateral to the propagation direction toward a particular area on the transmitting surface; and

wherein the particular area and the reflecting surface are disposed so that greater than about 90% of electromagnetic radiation reflected by the reflecting surface is incident on the particular area at below a critical angle for transmission through the transmitting surface in the lateral direction.

2. The apparatus of claim 1, wherein the tip of the waveguide comprises a fiber optic segment, the fiber optic segment including a fiber core having an outside radius R1 and a core cladding having an outside radius R2 and a cylindrical outside surface, wherein R2 is equal to greater than about 1.4 times R1; and wherein the reflecting surface comprises a bevelled surface on the fiber core at a distal end of the tip and the transmitting surface comprises a portion of the cylindrical outside surface of the core cladding.

3. The apparatus of claim 2, wherein the fiber core comprises fused quartz, and the core cladding comprises doped fused quartz.

4. The apparatus of claim 1, wherein the tip of the waveguide comprises a fiber optic segment, the fiber optic segment including a fiber core having an outside radius R1, a bevelled end surface, and an index of refraction N1, and a core cladding having an outside radius R2, an index of refraction N2 and a cylindrical outside surface, wherein the reflecting surface comprises an interface between an external medium and the bevelled end surface on the fiber core at a distal end of the tip and the transmitting surface comprises a portion of the cylindrical outside surface of the core cladding, the external medium having index of refraction NA, and wherein R2/R1 is greater than or equal to about N2/NA.

5. An apparatus for communicating and laterally directing electromagnetic radiation, comprising:

a waveguide core having a cylindrical peripheral surface with radius R1, and comprising a transmissive material having a first index of refraction, through which electromagnetic radiation is transmitted in a propagation direction;

a bevelled tip on the waveguide core to reflect electromagnetic radiation transmitted through the waveguide core in a lateral direction relative to the propagation directions through the core;

core cladding comprising a transmissive material having a second index of refraction sightly less than the first index of refraction, disposed on the peripheral surface of the waveguide core at least in a region near the bevelled tip through which electromagnetic radiation propagating in the lateral direction from the bevelled tip is transmitted, and having a cylindrical outside surface in said region with radius R2 exposed to a medium having a third index of refraction less than the second index of refraction;

wherein R1 is essentially k times R2, and k is less than or equal to the third index of refraction divided by the second index of refraction.

6. The apparatus of claim 5, wherein the waveguide core comprises fused quartz, the core cladding comprises doped fused quartz.

7. An apparatus for communicating and laterally directing electromagnetic radiation, comprising:

a waveguide having a tip for communicating electromagnetic radiation in a propagation direction to the tip of the waveguide;

a reflecting surface on the tip of the waveguide for internally reflecting electromagnetic radiation communicated in the propagation direction by the waveguide in a lateral direction relative to the propagation direction;

a transmitting surface on the tip of the waveguide having a particular area within which radiation propagating in the lateral direction is incident at below a critical angle for transmission through the transmitting surface;

said reflecting surface and said particular area having first and second widths, respectively, transverse to the propagation direction, and wherein the second width is essentially equal to or greater than the first width.

8. The apparatus of claim 7, wherein the reflecting surface comprises a bevelled surface at a distal end of the tip.

9. The apparatus of claim 8, wherein the tip comprises quartz and the bevelled surface is disposed at an angle of about thirty-eight (38) degrees relative to the propagation direction.

10. The apparatus of claim 8, wherein the tip has two opposing sides in respective planes parallel to the lateral direction such that the particular area is limited by an intersection of the two opposing sides and the bevelled surface with the transmitting surface.

11. The apparatus of claim 10, wherein the transmitting surface has a cylindrical curve and the two opposing sides intersect the cylindrical curve at below a critical angle.

12. The apparatus of claim 10, wherein the transmitting surface is essentially flat.

13. The apparatus of claim 8, wherein the tip has sides intersecting the transmitting surface and extending to the bevelled surface to define a shape of the reflecting surface so that electromagnetic radiation reflected by the reflecting surface does not strike the sides.

14. The apparatus of claim 13, wherein the tip has a triangular cross-section.

15. The apparatus of claim 13, wherein the tip has a rectangular cross-section.

16. The apparatus of claim 7, further comprising:

a transparent cap secured to the waveguide and enclosing the reflecting surface on the tip.

31

20
17. The apparatus of claim 7, further comprising:

a transparent cap, secured to the tip and enclosing the reflecting surface and the transmitting surface, forming a sealed cavity adjacent to the reflecting surface for maintaining a selected medium within the cavity adjacent to the reflecting surface.

18. The apparatus of claim 7, further comprising:

a tube with a hollow inside having a first end secured to the tip and enclosing the reflecting surface and the transmitting surface, the hollow inside of the tube positioned against and forming a cavity adjacent to the reflecting surface, and a second end of the tube having a plug for maintaining a selected medium within the cavity adjacent to the reflecting surface.

16
19. The apparatus of claim 8, wherein the waveguide comprises an optical fiber.

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20. The apparatus of claim 19, wherein the optical fiber has a relatively high index of refraction of about 1.62, and the bevelled surface is disposed at an angle of about 45 degrees relative to the propagation direction.

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21. The apparatus of claim 7, wherein the tip comprises a piece of material coupled to the end of the waveguide.

37

22. The apparatus of claim 7, wherein at least the tip of the waveguide comprises an optical fiber having a fiber core with a radius R_1, and transmissive core cladding on the fiber core with an outside surface defining a critical angle between the core cladding and an outside medium and a radius R_2, and wherein the radius R_2 is equal to or greater than about R_1 divided by sine of the critical angle between the core cladding and the outside medium.

23. The apparatus of claim 7, wherein the tip of the waveguide comprises a fiber optic segment, the fiber optic segment including a fiber core having an outside radius R1 and a core cladding having an outside radius R2 and a cylindrical outside surface, wherein R2 is equal to greater than about 1.4 times R1; and wherein the reflecting surface comprises a bevelled surface on the fiber core at a distal end of the tip and the transmitting surface comprises a portion of the cylindrical outside surface of the core cladding.

24. The apparatus of claim 23, wherein the fiber core comprises fused quartz, and the core cladding comprises doped fused quartz.

25. The apparatus of claim 7, wherein the tip of the waveguide comprises a fiber optic segment, the fiber optic segment including a fiber core having an outside radius R1, a bevelled end surface, and an index of refraction N1, and a core cladding having an outside radius R2, an index of refraction N2 and a cylindrical outside surface, wherein the reflecting surface comprises an interface between an external medium and the bevelled end surface on the fiber core at a distal end of the tip and the transmitting surface comprises a portion of the cylindrical outside surface of the core cladding, the external medium, having index of refraction NA, and wherein R2/R1 is greater than or equal to about N2/NA.

26. A surgical probe for treating benign prostatic hyperplasia (BPH), said probe, comprising:

a waveguide having a tip, the waveguide for communicating electromagnetic radiation in a first propagation direction to the tip of the waveguide;

means for positioning the waveguide during surgery;

a transmitting surface on the tip of the waveguide;

a reflecting surface on the tip of the waveguide for internally reflecting electromagnetic radiation communicated in the first propagation direction by the waveguide in a second propagation direction toward the transmitting surface; and

wherein substantially all electromagnetic radiation reflected by the reflecting surface is incident on the transmitting surface at below a critical angle for transmission through the transmitting surface.

27. The apparatus of claim 26, wherein the means for positioning the waveguide includes a tube having a hollow passage, and the waveguide is positioned within the hollow passage.

28. The apparatus of claim 27, wherein the tube comprises a rigid cannula.

29. The apparatus of claim 27, wherein the tube comprises a flexible catheter.

30. The apparatus of claim 25, wherein the reflecting surface comprises a bevelled surface at the distal end of the tip.

31. The apparatus of claim 30, wherein the tip has two opposing sides in respective planes parallel to the second propagation direction so that the reflecting surface is limited by an intersection of the two opposing sides and the bevelled surface.

32. The apparatus of claim 30, wherein the tip has sides intersecting the transmitting surface and extending to the bevelled surface to define a shape of the reflecting surface so that electromagnetic radiation reflected by the reflecting surface does not strike the sides.

33. The apparatus of claim 25, wherein the tip of the waveguide comprises a fiber optic segment, the fiber optic segment including a fiber core having an outside radius R1 and a core cladding having an outside radius R2 and a cylindrical outside surface, wherein R2 is equal to greater than about 1.4 times R1; and wherein the reflecting surface comprises a bevelled surface on the fiber core at a distal end of the tip and the transmitting surface comprises a portion of the cylindrical outside surface of the core cladding.

34. The apparatus of claim 33, wherein the fiber core comprises fused quartz, and the core cladding comprises doped fused quartz.

35

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35. The apparatus of claim 26, wherein the tip of the waveguide comprises a fiber optic segment, the fiber optic segment including a fiber core having an outside radius R1, a bevelled end surface, and an index of refraction N1, and a core cladding having an outside radius R2, an index of refraction N2 and a cylindrical outside surface, wherein the reflecting surface comprises an interface between an external medium and the bevelled end surface on the fiber core at a distal end of the tip and the transmitting surface comprises a portion of the cylindrical outside surface of the core cladding, the external medium having index of refraction NA, and wherein R2/R1 is greater than or equal to about N2/NA.

36